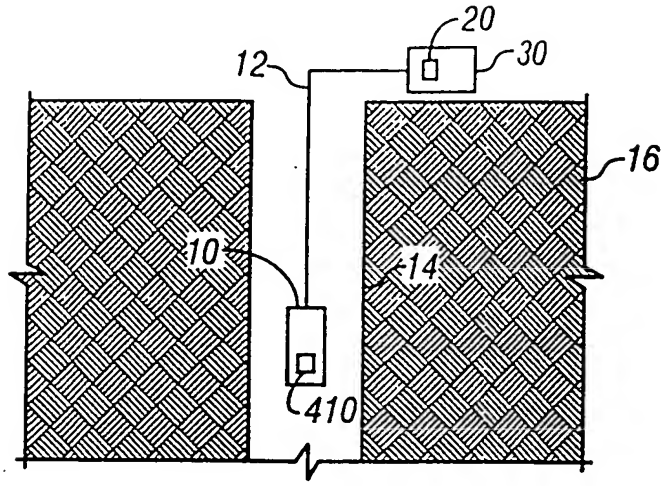


FIG. 1

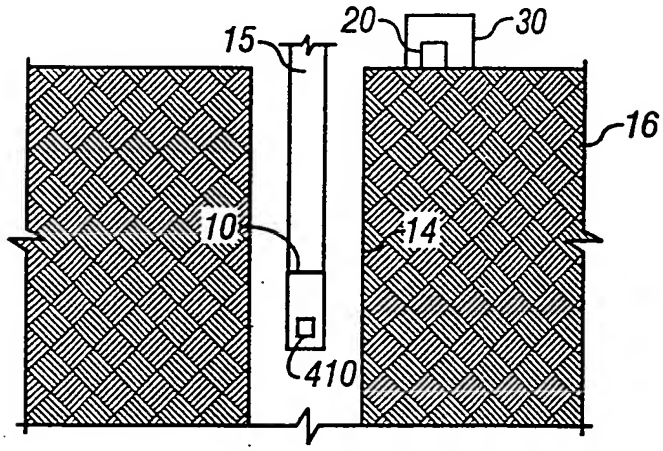


FIG. 2

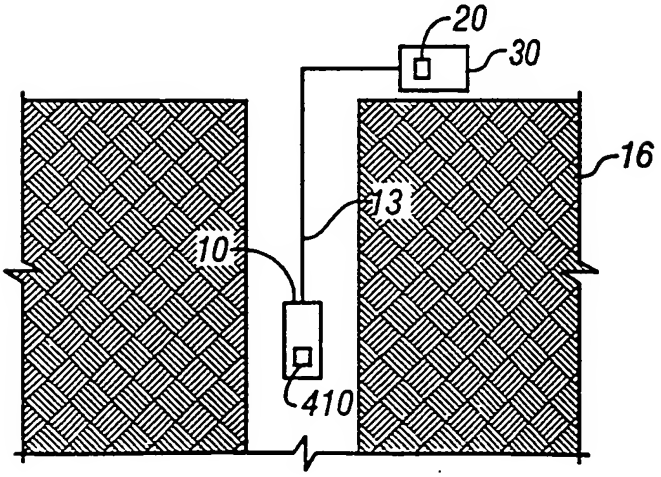


FIG. 3

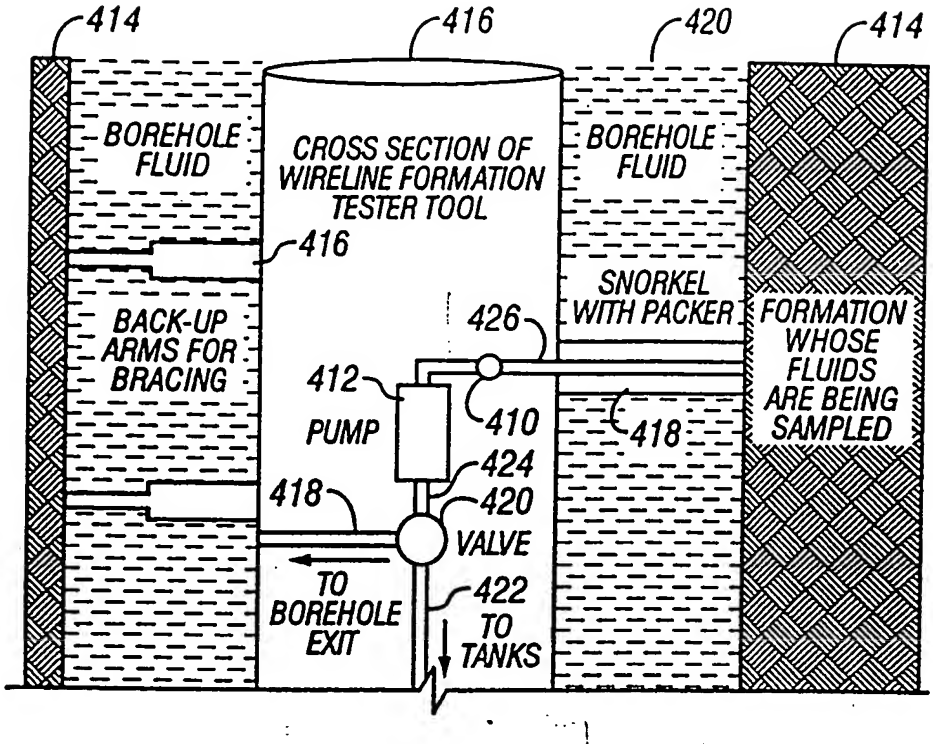
414
416
420
414
BOREHOLE FLUID
CROSS SECTION OF WIRELINE FORMATION TESTER TOOL
BOREHOLE FLUID
416
SNORKEL WITH PACKER
426
FORMATION WHOSE FLUIDS ARE BEING SAMPLED
BACK-UP ARMS FOR BRACING
412
PUMP
410
418
424
418
420
VALVE
TO BOREHOLE EXIT
422
TO TANKS

FIG. 4

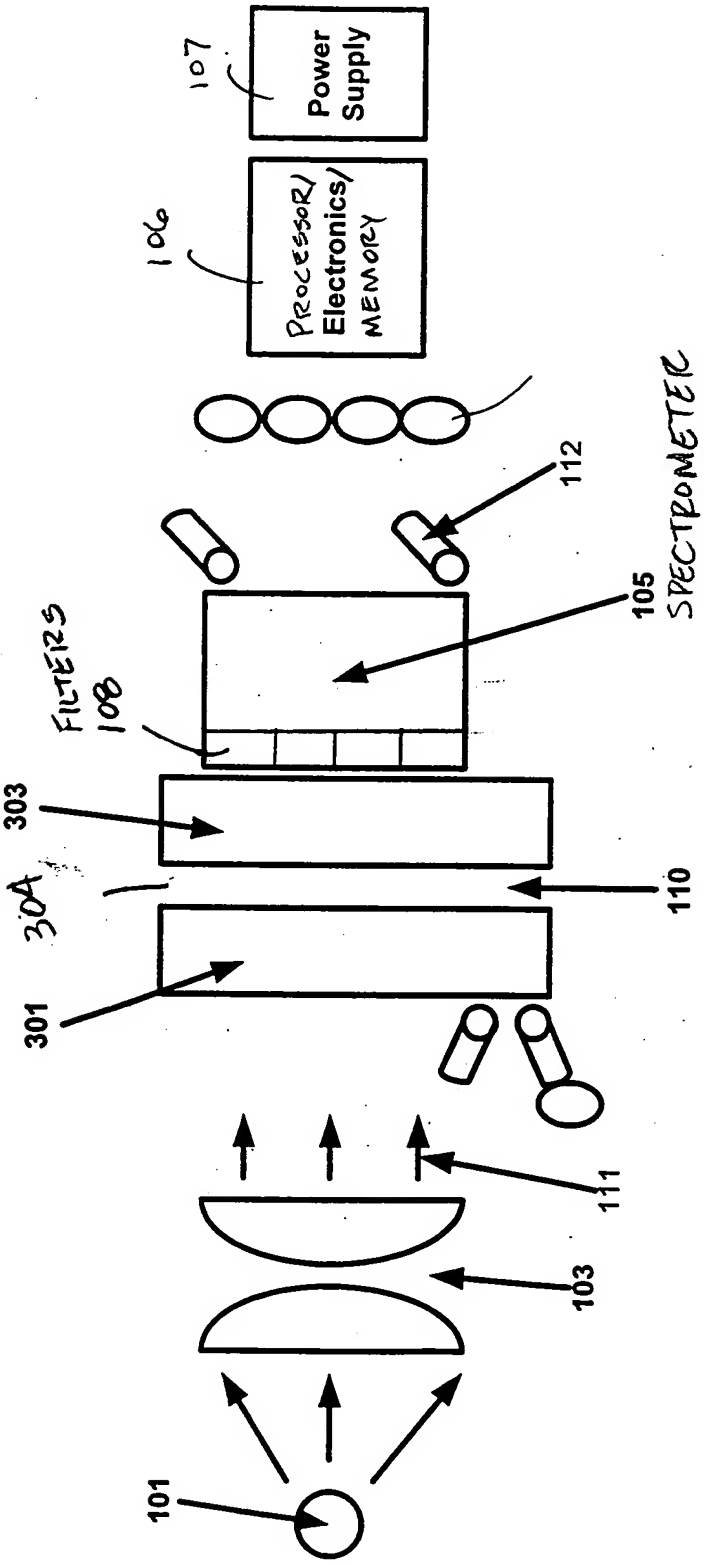
Power Supply
107
Processor/ Electronics/ Memory
106
112
105
SPECTROMETER
FILTERS
108
303
304
110
301
111
103
101

FIG. 5

## Equations Correlating Weight Fraction Methane in Mixtures of Crude Oil and Methane to Optical Absorbance and Temperature

FIG. 6

Methane Weight Fraction = **METHWTF = B0 + B1 * Var1 + B2 * Var2 + B3 * Var3 + B4 * Var4 ...**

Regression Summary for Dependent Variable: **METHWTF**
R= .98093203 $R^2$= .96222765 Adjusted $R^2$= .96151158
F(4,211)=1343.8 p<0.0000 Std.Error of estimate: .04992

| | | B | |
|---|---|---|---|
| | | 0.06514 | = B0 = Intercept |
| Var1 = | SQ70_82 | 11.1756 | = B1 |
| Var2 = | TEMP_C | 0.00087 | = B2 |
| Var3 = | SRSA1682 | -2.66167 | = B3 |
| Var4 = | SRSA1670 | 2.63245 | = B4 |

**SQ70-82** = SQUARE(Absorbance_at_1670_nm - Absorbance_at_1682_nm)
**SRSA1670** = SQRT(Absorbance_at_1670_nm)
**SRSA1682** = SQRT(Absorbance_at_1682_nm)
**TEMP_C** = Temperature in Degrees Centrigrade
**TEMP_SQR** = Square of Temperature in Degrees C

**Equation for Density of Methane [g/cc] as a Function of Pressure and Temperature** from 100 - 30,000 psia and 75 - 200 C is fitted by Adj. $R^2$= .99911359

| | B | |
|---|---|---|
| | 2.771E-03 | = Intercept |
| P | 2.480E-05 | |
| $P^2$ | -1.120E-09 | for Pressure in psi |
| $P^3$ | 1.808E-14 | |
| $T^2$ | -1.308E-07 | for Temperature in C |
| (P/T) | 1.455E-03 | |
| $(P/T)^2$ | -4.922E-06 | |
| $(P/T)^3$ | 5.934E-09 | |

**Equation for Optical Absorbance per mm of Methane as Function of Density and Wavelength** at 11 nm FWHM, Center λ range of 1668-1684 nm, for 100-30,000 psia, and 75 - 200 C, is fitted by Adj. $R^2$= .94145159

| | B | |
|---|---|---|
| | -19.9061 | = Intercept |
| Methane Density | 0.7747 | for Density in g/cc |
| WaveNumber/1000 | 3.3326 | |

where, WaveNumber ≡ 10 000 000 / λ [nm]

Regression Summary for Dependent Variable: **METHWTF**
R= .98190316 $R^2$= .96413381 Adjusted $R^2$= .96327986
F(5,210)=1129.0 p<0.0000 Std.Error of estimate: .04876

| | | B | |
|---|---|---|---|
| | | 0.03143 | = B0 = Intercept |
| Var1 = | SRSA1670 | 2.53111 | = B1 |
| Var2 = | SRSA1682 | -2.55766 | = B2 |
| Var3 = | SQ70_82 | 11.9135 | = B3 |
| Var4 = | TEMP_C | 0.0019 | = B4 |
| Var5 = | TEMP_SQR | -6.2E-06 | = B5 |

**Equations Relating Gas Oil Ratio, GOR, to Weight Fraction of Methane, $f_M$, and Stock Tank Density, $\rho_O$, of Oil**

1 bbl = 0.159 $m^3$=5.615 cu ft=42 U.S. gal
1 Standard Cubic Foot (SCF) of Methane Gas at 14.7 psia & 60°F is 0.042358 lbs = 19.21327 grams.
Density of Methane at 60 F and 14.7 psia is 0.0006787 gr/cc = 0.042358 lbm/$ft^3$.
Letting V = Volume, W = Weight, ρ = Density, and using **subscripts M for Methane and O for Oil,**
GOR ≡ $V_{Methane}$ [SCF] / $V_{Oil}$ [bbls] = { $W_M$ / (19.21 g/SCF) } / { ( $W_O$ / $\rho_O$ ) ( 1 bbl / 158 983 cc ) }
Letting $f_M$ = Weight Fraction of Methane,
**GOR = 8274.62 $\rho_O$ / ( 1 / $f_M$ - 1 )**
$f_M \equiv W_M / ( W_M + W_O ) = \rho_M V_M / ( \rho_M V_M + \rho_O V_O )$ so $W_O = W_M / ( 1 / f_M - 1 )$ which substitutes into above.
**$f_M$ = 1 / ( 1 + 8274.62 * $\rho_O$ / GOR )** where $W_G$ and $W_O$ are in grams, $\rho_O$ is in g/cc, and $f_M$ = Wt. Frac. of Methane

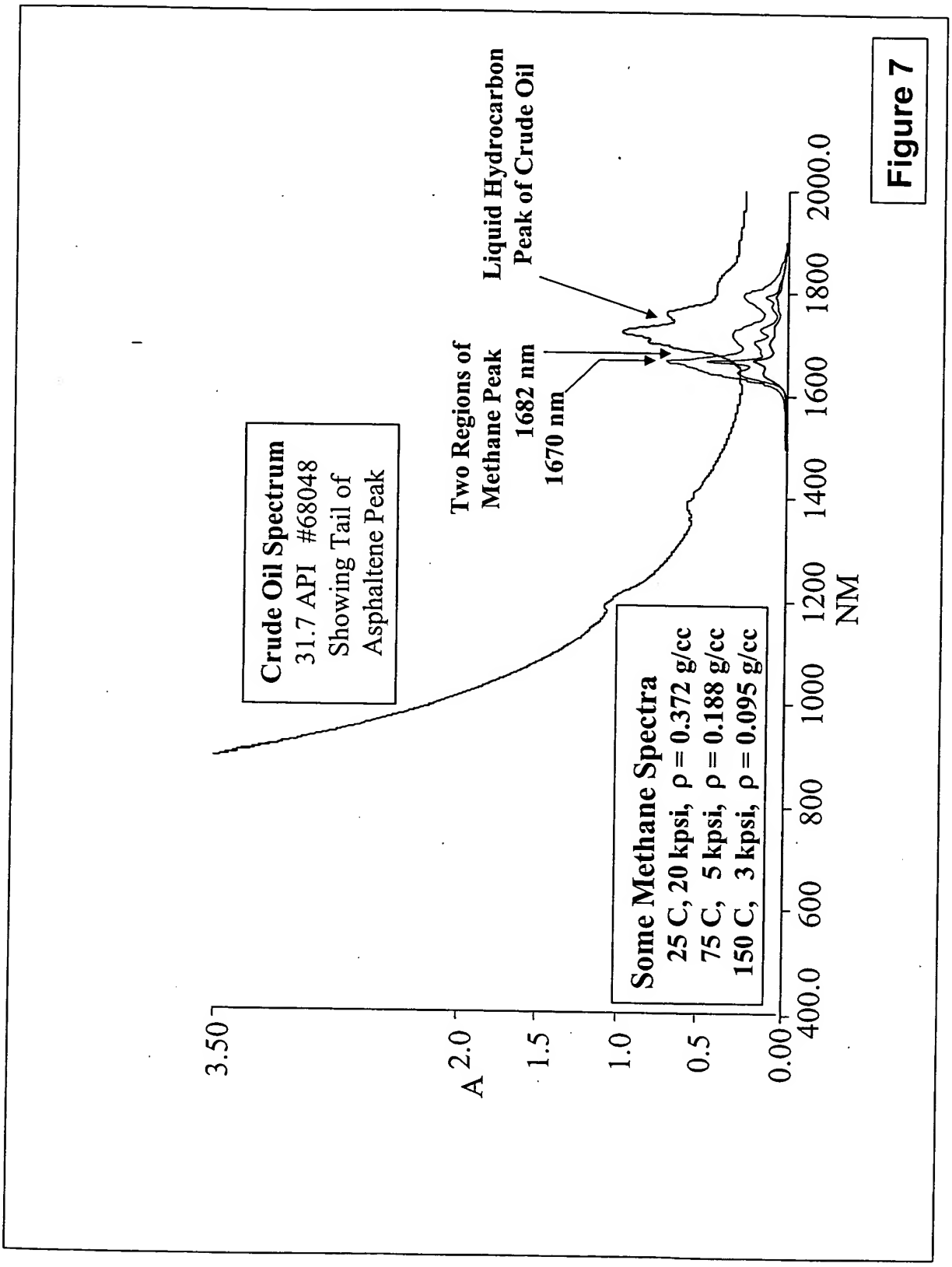
Crude Oil Spectrum
31.7 API #68048
Showing Tail of
Asphaltene Peak
Two Regions of
Methane Peak
1682 nm
1670 nm
Liquid Hydrocarbon
Peak of Crude Oil
Some Methane Spectra
25 C, 20 kpsi, ρ = 0.372 g/cc
75 C, 5 kpsi, ρ = 0.188 g/cc
150 C, 3 kpsi, ρ = 0.095 g/cc
A
3.50
2.0
1.5
1.0
0.5
0.00
400.0
600
800
1000
1200
1400
1600
1800
2000.0
NM

Figure 7

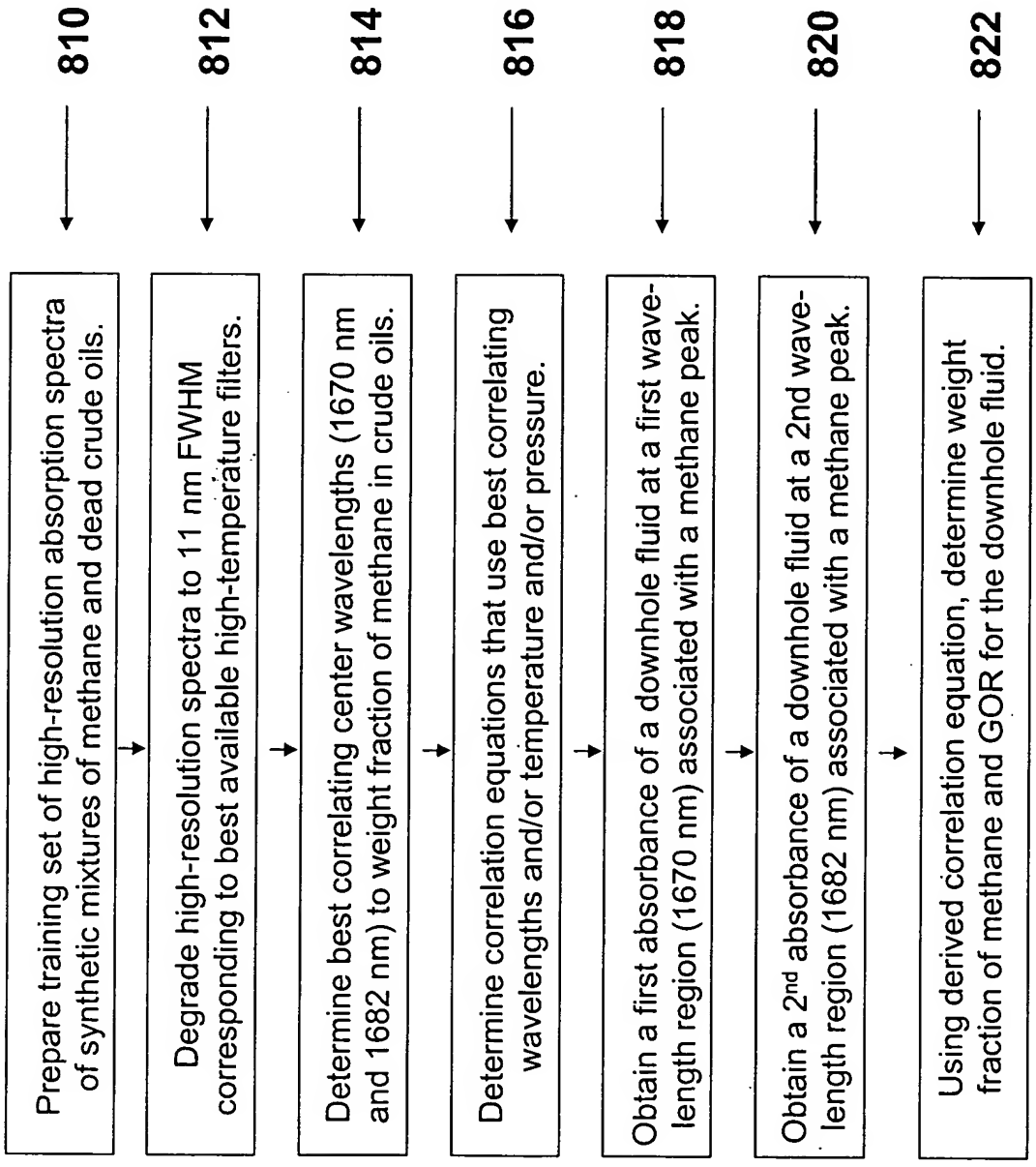
Prepare training set of high-resolution absorption spectra of synthetic mixtures of methane and dead crude oils.
810
Degrade high-resolution spectra to 11 nm FWHM corresponding to best available high-temperature filters.
812
Determine best correlating center wavelengths (1670 nm and 1682 nm) to weight fraction of methane in crude oils.
814
Determine correlation equations that use best correlating wavelengths and/or temperature and/or pressure.
816
Obtain a first absorbance of a downhole fluid at a first wavelength region (1670 nm) associated with a methane peak.
818
Obtain a 2nd absorbance of a downhole fluid at a 2nd wavelength region (1682 nm) associated with a methane peak.
820
Using derived correlation equation, determine weight fraction of methane and GOR for the downhole fluid.
822

Figure 8